Investigation of Laser-Produced Plasmas of Mo, Ru, Rh and Pd in the 2.4 nm to 13 nm Spectral Region

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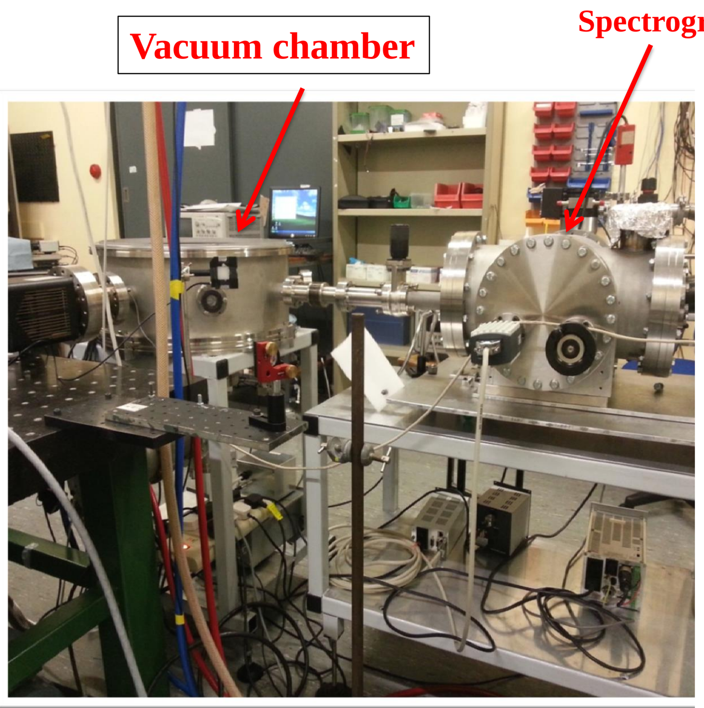
1.Abstract

The Rayleigh criterion resolution implies that the use of shorter wavelength radiation improves spatial resolution in photon based imaging and patterning systems. Over the past decade the development of sources at extreme ultraviolet and even shorter, soft X-ray wavelength is of a great interest for semiconductor patterning and cellular microscopy where high resolution is required. In the work presented here the spectra of laser plasmas of Mo, Ru, Rh and Pd in the spectral region from 2.4 nm to 13 nm, as potential new sources of radiation for these applications. The laser energy range covered by the experiments was from 587mJ to 10mJ. Spectral analysis of emission from different ion stages were carried out with the aid of calculations for transition wavelengths and intensities using the atomic structure code of Cowan for the different ion stages identified and isoelectronic comparison with known Mo lines [1]. Mean wavelength were calculated by UTA formalism [3].

2.Experimental setup



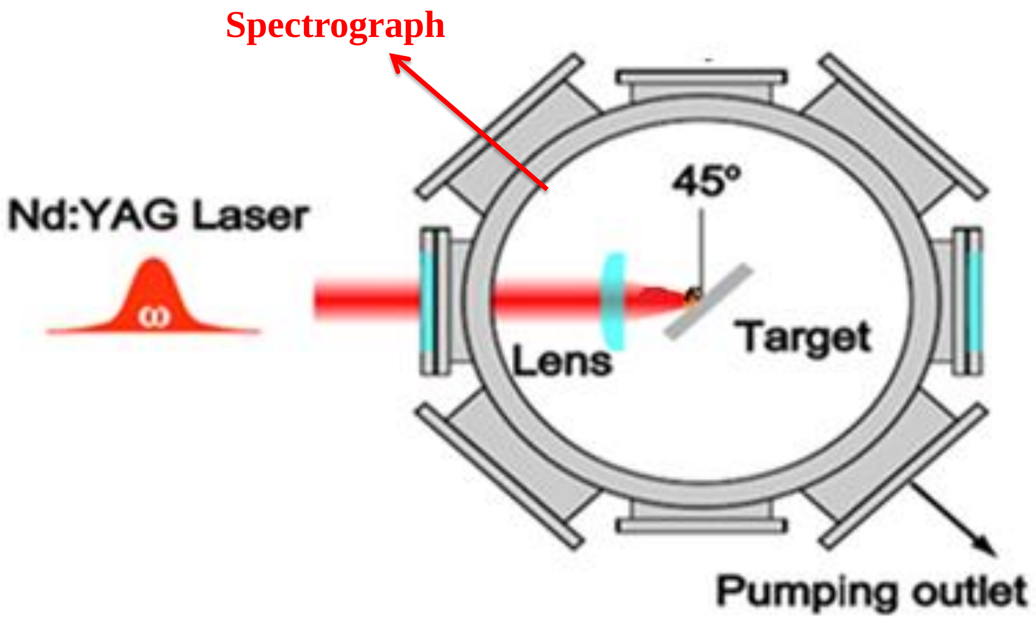


Figure 1: Experimental setup& Schematic of the experiment. Pulses from an Ekspla SL312P 150 picosecond and a Surelite 7ns Nd:YAG laser were focused on solid targets of molybdenum, ruthenium, rhodium&palladium

Laser Parameters Used [2]

Element	NS Power density W/cm^2	Electron temp (eV) [2]	PS Power density W/Elements cm^2
Mo, Ru, Rh, Pd	2.49E13(587mJ)	1290.3	
Mo, Ru, Rh, Pd	1.69E13(397mJ)	1022.6	1.20E15
Mo, Ru, Rh, Pd	4.25E12(100mJ)	446.7	5.27E14
Mo, Ru, Rh, Pd	1.23E12(30mJ)	212.2	1.53E14
Mo, Ru, Rh, Pd	4.20E11(10mJ)	111.4	5.04E13

3.Results

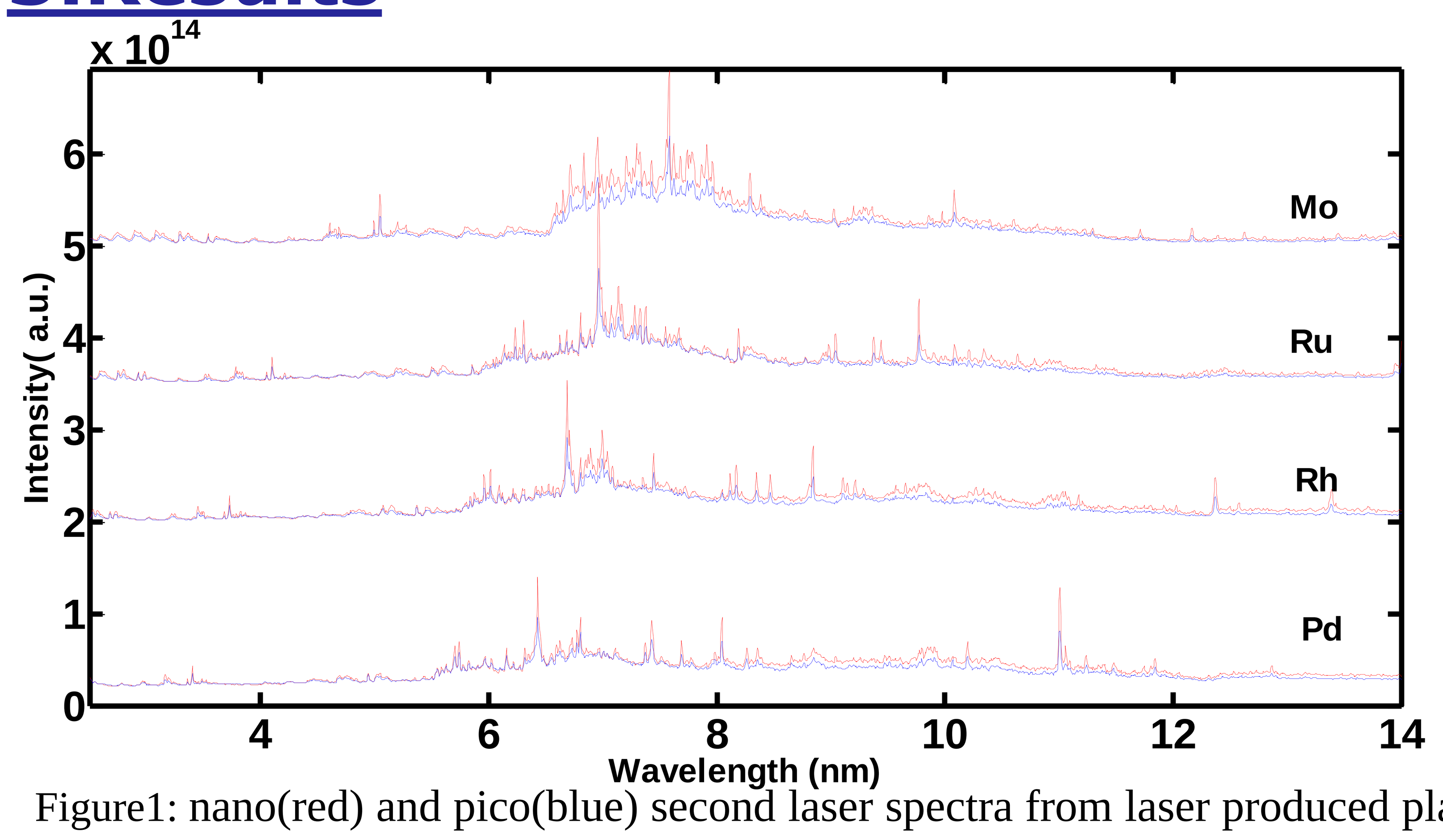
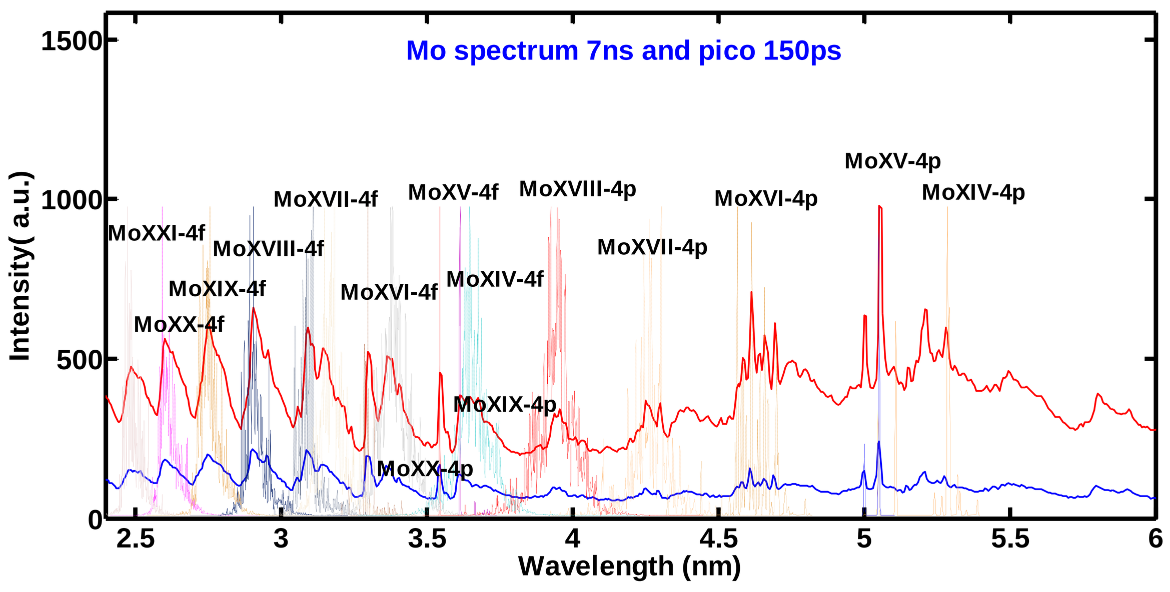
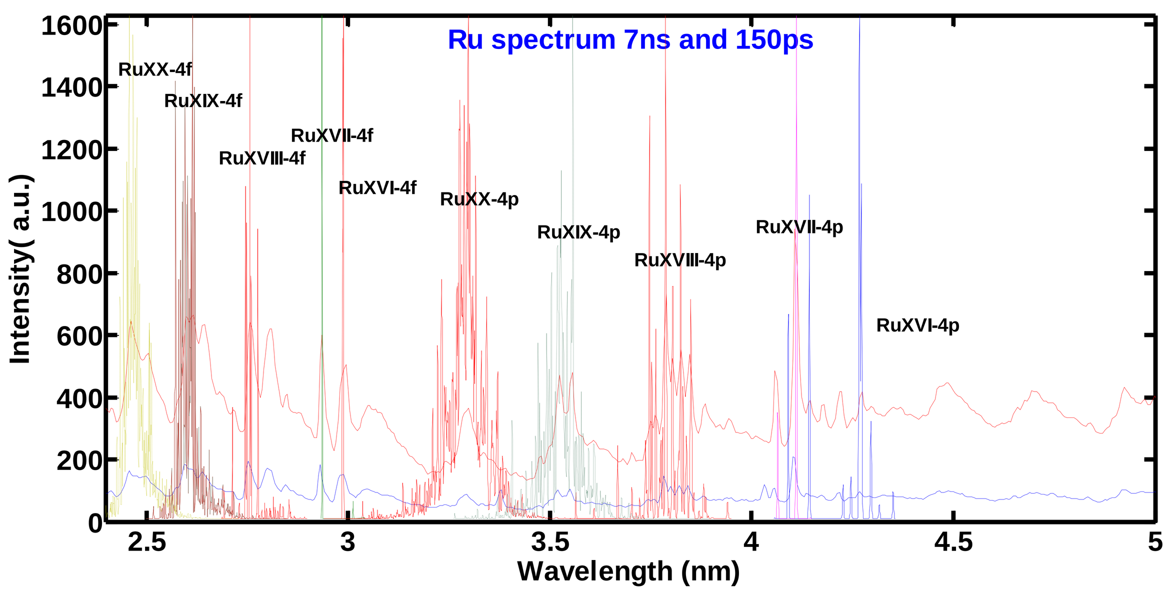


Figure1: nano(red) and pico(blue) second laser spectra from laser produced plasmas of Mo, Ru, Rh and Pd. The high intensity peak is arising from $3p^n$-$3p^{n-1}\,3d^{n+1}$ transitions.





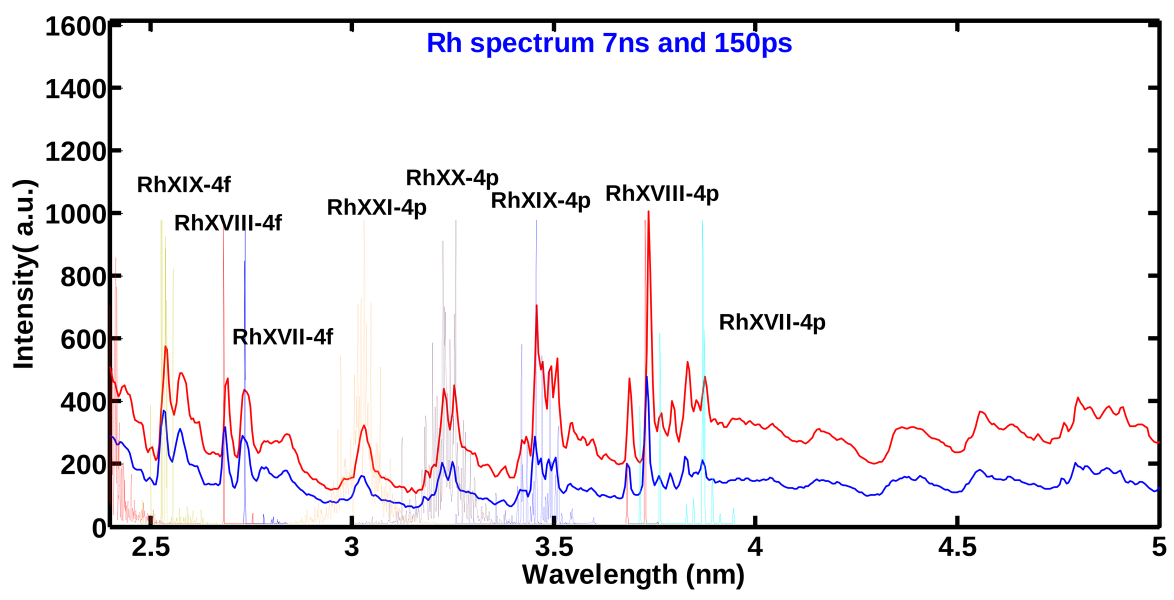
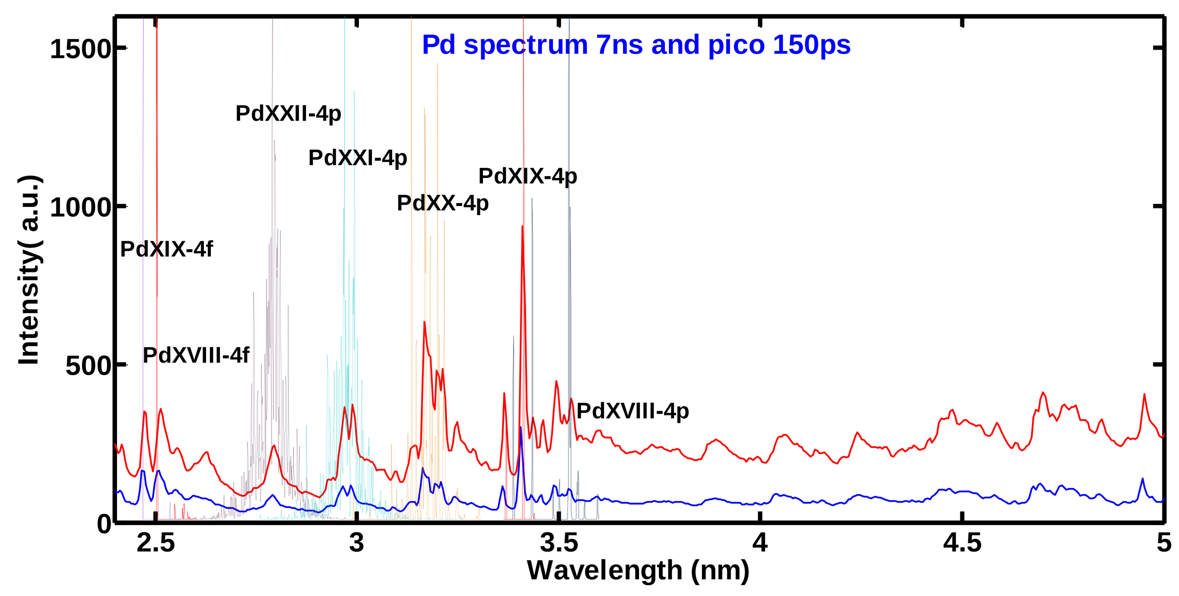
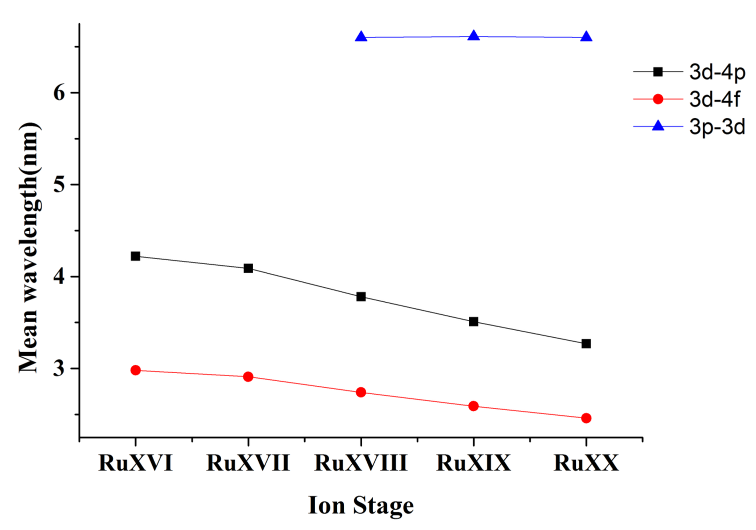
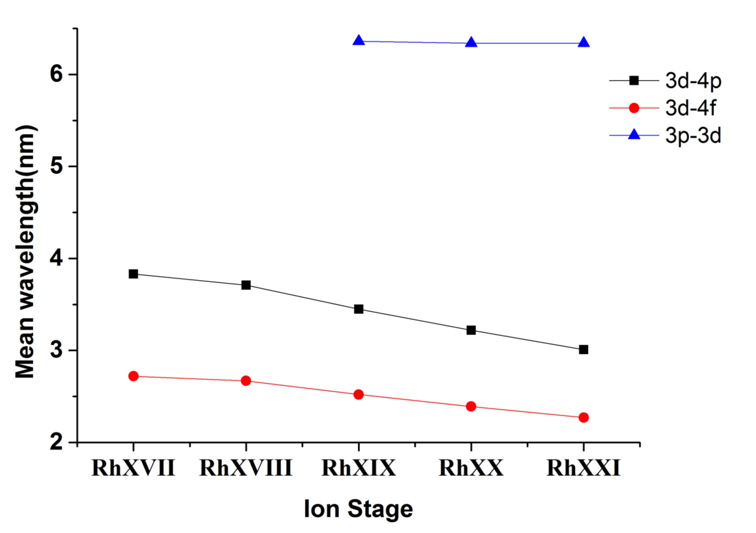


Figure 1 to3: Spectral behavior of Mo,Ru and Rh plasmas showing with Ion 3d-4p,3d-4f transitions along with Cowan synthetic spectra of each ion stage.Variation of spectral emission recorded with pico and nano laser.







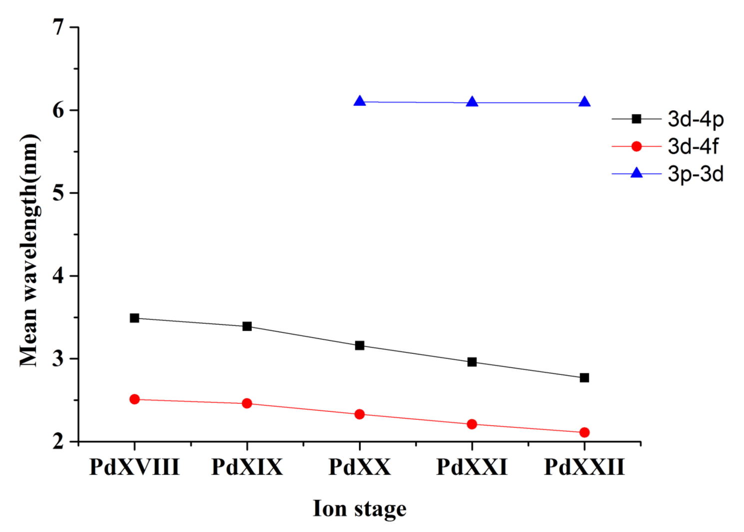


Figure 4: Spectral behavior of Pd plasmas showing with Ion 3d-4p,3d-4f transitions along with Cowan synthetic spectra of each ion stage.Variation of spectral emission recorded with pico and nano laser. Fig:5to 7 Mean calculated wavelength [3] for the different Ru, Rh and Pd ions for different transitions.

4.Conclusion

- We have observed emission in the 6.x spectral region from laser produced Ru,Rh & Pd plasmas.
- Theoretical spectra were calculated using Hartree-Fock configuration-interaction numerical method and compared with experimental spectra and identified ion stages of 3d-4p.3d-4f transition arrays for Ru,Rh and Pd
- For increasing nuclear charge, lines in isoelectronic sequences move to shorter wavelengths The laser produced plasma technique may be employed in future work to generate these radiation sources
- A comparison of spectral emission around the "water window" (2.4 nm to 4.3 nm) which is useful for bioimaging suggests that Mo is the strongest emitter.
- A comparison of emission in the 6.x nm spectral region, which has potential applications in future nano-patterning for lithography, suggests that the best emitters are Ru and Rh.

Ref: [1] R. D. Cowan, The Theory of Atomic Structure and Spectra (University of California Press, Berkeley, CA, 1981).
[2] D.Colombant, G.F.Tonan-X-ray emission in laser-produced plasma, electron temperature
[3] J. Bauche, C. Bauche-Arnoult and M. Klapisch Adv. At. Mol. Phys. 27, 131 (1987)

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